MINERALOGY AND ORIGIN OF BRASSY, SULFIDE-RICH MASSES IN THE GIBEON IVA IRON Michail I. Petaev and Ursula B. Marvin, Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138

In addition to spheroids [1] and small sulfide grains [2], the two slices of Gibeon we have studied [1-3] contain brassy metal-troilite-daubréelite masses, which are mineralogically similar to spheroids we have reported in vugs in the Albion and Gibeon meteorites [1,4,5].

In Slice V (for description see [1]) sulfide-rich masses are enclosed in the metal of the Widmanstätten pattern (Fig. 1a,b). In Slice S (see [3]) brassy masses are also present (Fig. 1c) in the midst of the Widmanstätten pattern, but they mainly occur at the boundary between the large tridymite lath and the metal (Fig. 1c,d). The masses isolated in metal always have irregular outlines with apophyses extending into metal, and are surrounded by more or less developed granulation zones (Fig. 1a-c). The brassy mineral assemblage appears to be invasive into the metal. Larger rounded brassy masses at the tridymite-metal interface tend to have, at least locally, a more or less smooth contact with the metal, being separated often from the latter by a thin rim (Fig. 1c,d) reminiscent of the rims of the Albion spheroids [4]. Here the granulation zone is typically absent.

Another type of sulfide-rich mineral assemblage is shown in Fig. 1e. Technically, this is not one of the brassy masses, but it has a very close genetic relationship to them. The tiny, 27×13 μm barred daubréelite crystal, at the interface between two kamacite bands, associates with high-Ni taenite, low-Ni kamacite, and troilite films decorated by tiny troilite lenses, suggestive of the corrosion of primary minerals of the Widmanstätten pattern by sulfur along with reequilibration of kamacite and taenite in contact with troilite. Neither the larger daubréelite crystal nor the zoned taenite ribbon, located just 100-150 μm away, are corroded by troilite.

Three types of occurrence of daubréelite were observed in the brassy masses. Typically, daubréelite occurs in μm-sized euhedral-to-subhedral grains or aggregates of them in a fine-grained metal-troilite groundmass (Fig. 2a). Larger grains are usually enclosed within low-Ni kamacite, which sometimes contains also wedges of high-Ni taenite (Fig. 2b). In several instances a fine-grained metal-sulfide groundmass encloses large broken crystals of daubréelite along with small euhedral crystals (Fig. 2c). The daubréelite fragments always are entirely surrounded by low-Ni kamacite. In rare cases (Fig. 2d) the daubréelite forms elongated crystals intergrown with small grains of low-Ni kamacite and enclosed within larger masses of metal. Small euhedral grains are present, but rare. In these instances no reaction between daubréelite and troilite was observed. On the contrary, grains of low-Ni kamacite, except for those enclosed within daubréelite, always have very ragged outlines at the interface with troilite, indicative of corrosion of the kamacite by the troilite.

Mineral compositions display only small variations, being very similar, if not identical, to those of the spheroids: low-Ni kamacite (1.8 - 4.4 wt.% Ni; 0.4 - 3.6 % Co; <0.6 % Cr), high-Ni taenite (51.6- 56.8 % Ni; <0.1 % Co), troilite (<0.5 % Cr). The large daubréelite grains are close to the ideal formula $FeCr_2S_4$, whereas smaller ones show a slight Fe excess, probably due to contamination with surrounding metal. Mineral modes (Table 1) of brassy masses estimated from BSE images vary considerably from mass to mass as well as within single masses, probably due to heterogeneity of precursor materials. However, troilite (Trl) and kamacite (Kam) always predominate over daubréelite (Dau) and taenite (Tae), respectively.

Table 1. Mineral modes (vol. %) of brassy masses

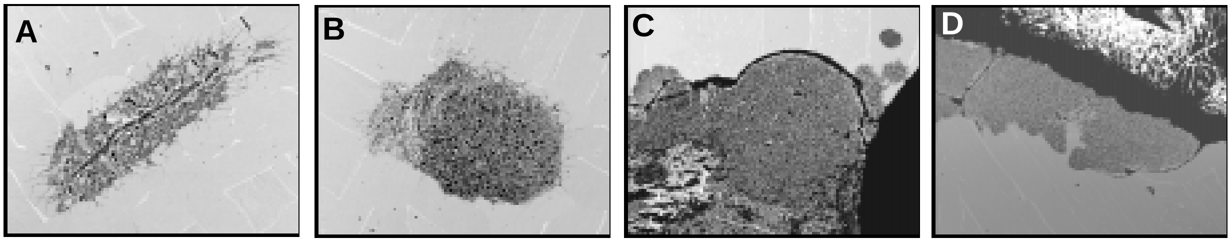
Image#	Trl	Dau	Kam	Tae
0053	40	17	41	2
0054	53	11	31	5
a020	53*	16	28	3
a021	51*	21	21	6
a014	38*	14	44	4
a015	44*	14	38	5
0042	63	14	23	0.04
0052	61	9	31	0.01

*Fine-grained intergrowths of troilite and metal

Both the coexistence of the high- and low-Ni metals, and the low Cr contents in troilite in the presence of daubréelite and metal, point to a low equilibration temperature of this mineral assemblage [5]. Moreover, phase diagrams of the Fe-Cr-S system [6,7,8] indicate that the textures and the crystallization sequence observed in the brassy masses (daubréelite → metal → troilite) cannot be formed by cooling from temperatures >600°C. Instead, this crystallization sequence requires reaction between kamacite and sulfur at relatively low temperatures.

The objects decribed above are typical of many IV irons, where they were previously reported to have been formed by shock-melting of preexisting troilite-daubréelite nodules [9]. The coexistence of high- and low-Ni metals was later explained by their crystallization during low-temperature devitrification of metallic glasses formed by shock-melting [10]. Here we suggest that the brassy mineral assemblage was formed *in situ* due to invasion of gaseous sulfur (sulfur metasomatism) along grain boundaries and cracks, and the reaction between sulfur and kamacite in the presence of daubréelite at low temperatures (Fig. 1e). Such a mechanism would account for textures and mineral compositions of the brassy masses in a way consistent with low-temperature phase relations in the Fe-Cr-S and Fe-Ni-S systems [7,8,11].

References: [1] Petaev M.I. et al. (1997) *this volume* [2] Petaev M.I. (1997) *this volume* [3] Marvin U.B. et al. (1997) *this volume* [4] Marvin U. B. et al (1996) *Meteorit. Planet. Sci.* Suppl. 31, A83 [5] Petaev M.I. and Marvin U.B. (1996) *ibid*, A107 [6] El Goresy A. and Kullerud G. (1968) *Carnegie Inst. Wash. Yearb.* **67**, 182 [7] Balabin A. I. et al. (1986) *Geokhimiya* **1**, 35 [8] Balabin A. I. (1996) *unpuslished data* [9] Buchwald V. F. (1975) *Handbook of Iron Meteorites* [10] Scott E.R.D. (1982) *GCA* **46**, 813 [11] Ma L. et al. (1995) *Meteoritics* **30**, 538



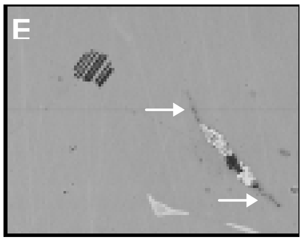


Fig. 1. Types of occurrence of brassy, sulfide-rich masses. BSE images. Widths of view: **a-d** = 2.38 mm; **e** = 380 µm. **a**. Slice V. Elongated brassy mass surrounds a long daubréelite crystal. Details are shown in Fig. 2d. **b**. Slice V. Brassy mass in metal. Texture is shown in Fig. 2b. **c**. Slice S. Rounded brassy masses at the interface between the tridymite lath (black at the right) and metal (light gray). The main mass is separated from the metal by a curved gap (crack?), but small isolated brassy masses occur within the Widmanstäten pattern. The fine-grained groundmass encloses the intergrowth of large daubréelite crystals with metal (left lower corner). **d**. Slice S. Brassy mass at the interface between the tridymite crystal (upper right) and metal (light gray). **e**. Barred daubrélites and taenite within the Widmanstätten pattern. Thin troilite film is shown by arrows. (see text)

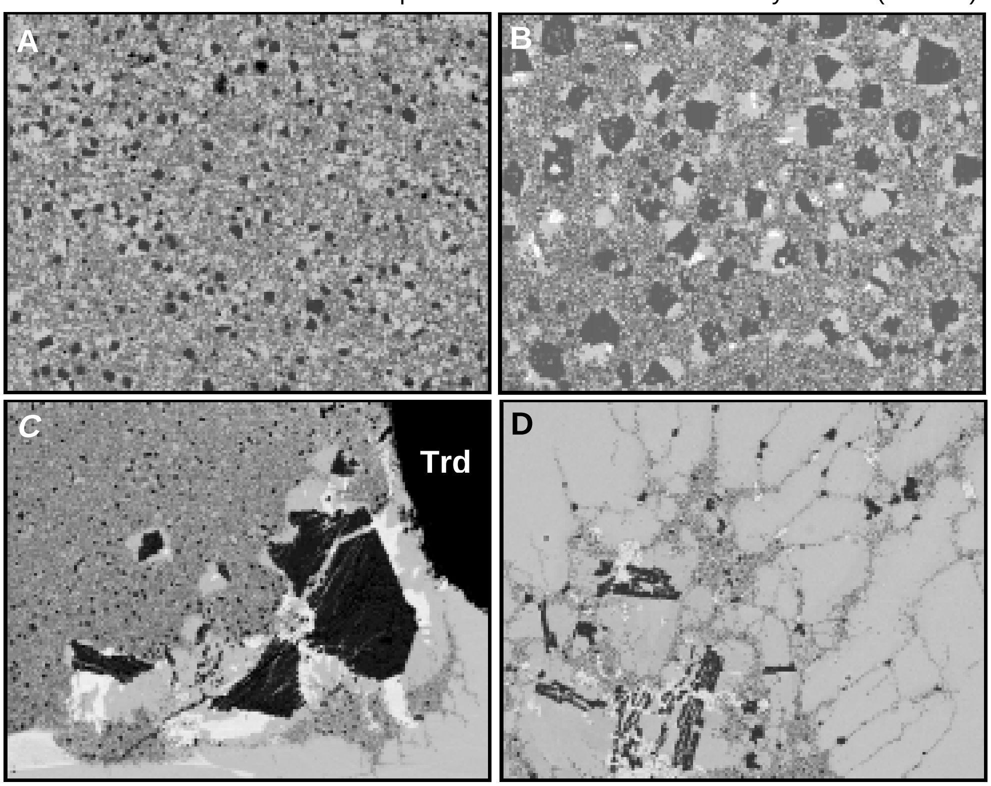


Fig. 2. Types of ocurrences of daubréelite in brassy masses. BSE images. White = high Ni taenite; light gray = low-Ni kamacite; dark gray = troilite; black = daubréelite. **a**. Small euhedral daubréelite crystals are disersed in the fine-grained kamacite-troilite groundmass. (Width of view 285 µm.) **b**. Metal-daubréelite intergowths embedded in the fine-grained kamacite-troilite groundmass. Some larger kamacite grains contain wedges of high-Ni taenite. (Width 380 µm.) **c**. Brassy mass encloses remnants of large broken daubréelite crystals which are completely surrounded by metal. Small euhedral daubréelite crystals are dispersed in the grained kamacite-troilite groundmass. Black phase is tridymite (Trd). (Width 760 µm.) **d**. Large barred daubréelite crystals are surrounded by metal which, in turn, is corroded my troilite. Small euhedral daubréelite crystals are dispersed in the well-developed granulation zone. (Width 570 µm.)